American scientist, the

SIGMA XI QUARTERLY

Vol. XIX MARCH, 1931 No. 1

CONVENTION NUMBER
MEES ON "PHOTOGRAPHY"

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Published by the Society of the Sigma Xi
at Easton, Pa.

ANNUAL SUBSCRIPTION $1.00 **SINGLE COPY 25 CENTS**

Changes of address of chapter members and associates should be communicated to chapter secretaries and to the national secretary.

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Entered as Second-class Matter, June 8, 1923, at the Post Office at Easton, Pa., under the act of August 24, 1912. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized June 8, 1923.

SIGMA XI QUARTERLY

Vol. XIX — March, 1931 — No. 1

THE SCIENCE OF PHOTOGRAPHY*

C. E. Kenneth Mees

Until quite recently, the scientific world has shown little interest in the science of photography as distinguished from its practice. Even the references to photographic theory in general textbooks are brief and frequently misleading. The introduction of sound into motion pictures, however, has brought the subject to the attention of a new section of the scientific public. That introduction was brought about by physicists and engineers trained primarily in the science of electricity, and when they started to apply the methods of sound recording to motion pictures, they were, of course, faced with photographic problems the pursuit of which brought them into contact rather closely with the development of photographic science.

The science of photography deals with the physics and chemistry of light-sensitive substances and especially of the silver compounds used in the art of photography. It touches at many points the fundamental sciences from which it is derived. Its physics is a branch of physical optics, and in chemistry it comes in contact principally with physical, colloid, and organic chemistry. The apparatus and methods used in photographic research have, however, become very specialized; its experimental methods are in many respects quite different from those employed in other fields of scientific work.

The subject falls naturally into two divisions: (Figure 1) (1) the study of the light-sensitive substance itself and the changes which it undergoes in its transformation into an image; (2) the properties of that image when obtained and their relation to the original distribution of light and shade by which the image was produced.

*Being the ninth annual Sigma Xi address, delivered December 30, 1930, on the occasion of the meeting of the American Association for the Advancement of Science, Cleveland, Ohio.

1. The light-sensitive substance which is used in modern photography, and which is known as the "emulsion," is produced by precipitating silver bromide—usually containing some silver iodide—in the presence of gelatin, washing out all the water soluble substances present, and drying it down into a thin film coated on a support, which may be glass, cellulose base film, or paper. The light-sensitive layer thus consists of a sheet of gelatin which, in the case of materials used for making negatives, is about 40 microns thick, and

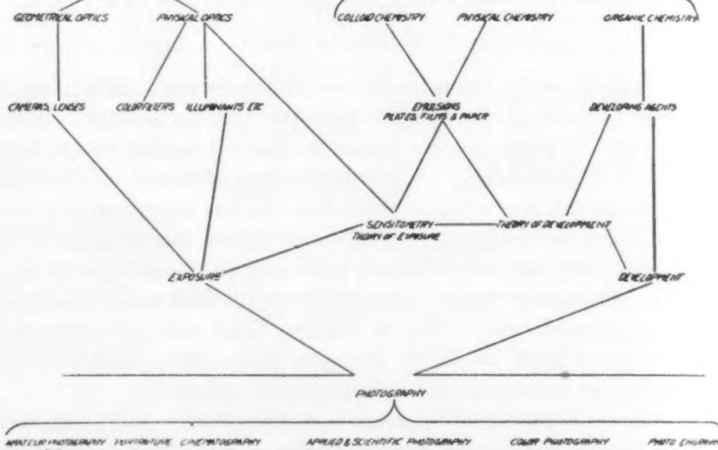

FIG. 1.—DIAGRAM OF RELATION OF SCIENCES.

in which are imbedded grains of silver bromide of an approximately triangular or hexagonal shape, varying in size from less than $^1/_2$ to 4 to 5 millimicrons in diameter. When these crystals are affected by light, they undergo a change, as a result of which, when placed in a photographic developer, which is an alkaline solution of a weak reducing agent, the silver bromide of the grain is transformed into micro-crystalline metallic silver.

The study of these phenomena can be divided into four different sections:

A. The nature of the change which the silver halide crystals undergo when they are affected by light.

B. The nature of the product of that change; that is, the material produced which enables development to be effected.

C. The physical chemistry of the development process itself.

D. The relation of the size and sensitiveness of the different crystals to the effect produced after development; that is, to the curve showing the relation between the exposure and the mass of silver produced.

These four sections, dealing with the phenomena of exposure and development, comprise that part of the science of photography which deals with the nature of the photographic process itself.

2. Further, the science of photography deals with the nature of the final image produced and its relation to the optical image from which it was formed. This also may be divided into sections:

E. The relation between the brightness of the various areas of the image and that of the corresponding areas of the original, which is known as "the theory of tone reproduction."

F. The structure of the image itself. The sharpness which is obtained in a photographic image is of importance primarily in connection with the resolving power of the photographic material. Photographic images show a certain amount of graininess, and in connection with their use as measuring instruments small distortions occur, the nature and extent of which have been studied.

G. The spectral sensitivity of the materials, both natural and after treatment with optical sensitizing dyes, occupies an important place in the science of photography.

H. Finally, in order to apply photographic materials in photometry, we need a knowledge of the theory of tone reproduction, the characteristic curve, the developing properties of the material, and the spectral sensitivity; in fact, we must be in a position to apply our whole knowledge of the science of photography to the subject.

In the early history of photography, investigators were occupied chiefly in attempting to improve the processes themselves with a view to obtaining photographic results of better quality or taking photographs with a shorter time of exposure. Whatever strictly scientific investigation there was was concerned with theories of the action of light and the part played by it in the production of the image. Quantitative measurements of the photographic process were not made until more than thirty years after photography had been established as a medium for the reproduction of images, and modern photographic science dates primarily from the publication in 1890 by Ferdinand Hurter and V. C. Driffield of a paper entitled "Photochemical Investigations," in which they studied systematically

the relation between exposure and development and the deposit of silver produced in the photographic process.

They first defined the photographic density, D, as being the logarithm of the *opacity*, which was defined as the inverse of the

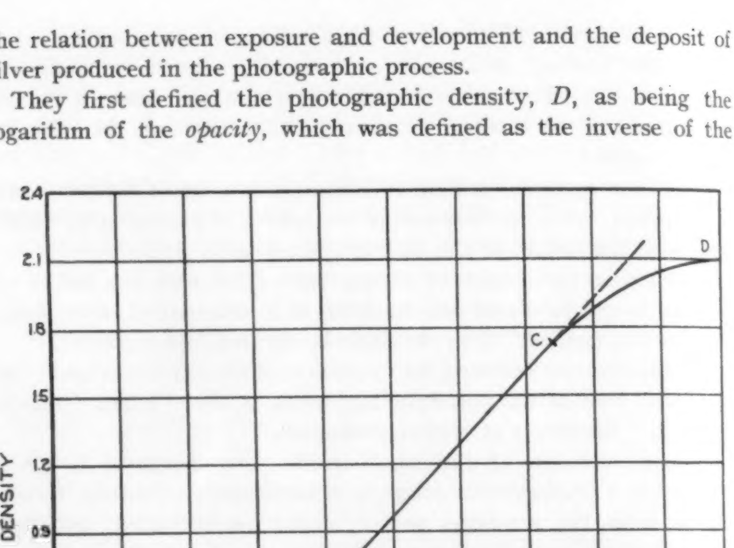

Fig. 2.—Characteristic Curve.

transparency. Thus, if we have a light of intensity, I, incident upon a photographic deposit, and I' is transmitted,

T (the transparency) $= I'/I$,

O (the opacity) $= I/I' = i/T$,

and D = density = logarithm of I/I' or $-\log I'/I$.

Hurter and Driffield showed experimentally that the density D of a given silver deposit is proportional to the mass of silver per unit area contained in the deposit. This result was confirmed by other workers, but it has recently been shown that the relation is only approximate and that there is a considerable departure from true proportionality with variations of exposure and development. A deposit transmitting approximately one-tenth of the incident light,

that is, having a density of 1, contains about $^1/_{10}$ mg. of silver per square centimeter of the film.

Basing their studies on their definition of density, Hurter and Driffield exposed photographic plates for definite times to a standard candle by means of a rotating wheel having cut-out sectors. The plates were developed, fixed, washed, dried, and the densities plotted on a chart with the logarithm of the exposure as abscissae and the densities as ordinates, as is shown in Figure 2. This shows what is known as the *characteristic* curve of an emulsion. There are three fairly well defined regions of the curve. Thus, from A to B, we have the initial part, convex to the *log E* axis, which may be termed the "region of under-exposure;" between B and C, known as the "region of correct exposure" (the increase of density is practically constant for each increase of exposure, being arithmetical for each geometric increase of exposure); and in the third region, from C to D, this arithmetical increase fails, until the density becomes constant; this is the "region of over-exposure." By prolongation of the straight-line portion of the curve, the *log E* axis is cut at a point which Hurter and Driffield termed the "inertia," which, when divided into a factor, gives the "speed" of the plate.

Hurter and Driffield studied the effect of the duration of development upon this characteristic curve and found that within certain limits the curve rotates around the inertia point, the effect of development being measured as an increase in the slope of the straight-line portion, which they termed the "development factor," and to which they assigned the Greek letter γ. The increase of γ with time of development is exponential, a limit being reached with prolonged development, which is generally known as gamma infinity ($\gamma\infty$). Photographic materials, therefore, may be classified by the values which they give for the *inertia*, a measure of the insensitiveness of the material, and of $\gamma\infty$, which is a measure of the limiting contrast which can be obtained, while the reproduction of tone values may be expressed as the *shape* of Hurter and Driffield's characteristic curve. Hurter and Driffield thus established photographic science on a firm quantitative basis, which the work of many other investigators has expanded and modified in details without affecting the foundation which they laid down.

Like all photographic investigators, Hurter and Driffield were interested in the reaction which silver halide undergoes when exposed to light and in the nature of the product of that reaction, on

which development is based. They thought that information as to this could be obtained from the work which they had done in measuring the quantitative relations of the image, but in the course of time it has become clear that the nature of the action of light upon the photographic material and of the product of that action must be sought by a study of the individual grains rather than by the measurement of the total density.

The study of the action of light on the individual crystal grains was commenced by Svedberg in Upsala in 1920. Svedberg spread out the emulsion in a very thin layer so that he could count the number of grains occurring in a unit area and classified these according to their size. Another portion of the layer was then exposed and developed and the silver removed by means of a silver solvent, and the grains of silver bromide which had not been developed and removed were then counted. In this way Svedberg established the fact that the likelihood of a grain becoming exposed followed the laws of probability, and that the larger grains were more likely to become exposed than the smaller grains. This work was followed up in England by the staff of the British Photographic Research Association and in our laboratory by S. E. Sheppard, A. P. H. Trivelli, E. P. Wightman, and others, and the sensitiveness relations of the individual grains of photographic emulsions were soon worked out. As an explanation of the facts found, Svedberg suggested that the sensitivity is concentrated in certain specks on the surface of the grains, and Clark and Toy of the British Research Association considered that these specks must be composed of some material alien to silver bromide. The nature of the specks has been elucidated as a result of the work by Sheppard on gelatin. Sheppard and Punnett had found that in gelatin there is present some material which, when added to an emulsion during manufacture, would enhance the sensitivity, and this material was found to be dissolved out during the acid wash which follows the liming of the raw materials used in the manufacture of photographic gelatin. Sheppard concentrated the material from the acid wash liquors and after a great deal of work identified it as allyl mustard oil. He showed that this, after being transformed into allyl thiocarbamide, reacts with silver bromide and forms a crystalline addition product which breaks down to give silver sulfide. The special sensitiveness of the silver bromide crystals occurring in high-speed emulsions can therefore be ascribed to the presence on their surface of ultra-microscopic specks

of silver sulfide. This suggestion, advanced in 1925, has met successfully the criticism directed against it and the theory is now generally accepted.

Throughout the history of photography there has been much controversy as to the nature of the material produced from light-sensitive materials by exposure to light which permits their subsequent development. The exposed material is generally said to contain a "latent image," and there has been much speculation as to the nature of this latent image. Some thirty years ago there were two rival theories on this subject, one school holding that the latent image consisted of a sub-halide of silver and the other that it consisted of metallic silver. There were various other suggestions, such as that the latent image represented merely a physical strain of some kind in the silver halide and not a definite chemical compound. At the present time, however, almost all photographic workers are agreed that the latent image is composed of metallic silver, which in development acts as a nucleus for the deposition of further silver produced by the reduction of the silver halide by the developer. A theory of the mechanism of exposure, therefore, has to account for the reduction of silver halide or silver sulfide or both to metallic silver at the points on a silver halide crystal where specks of silver sulfide occur. A number of hypotheses have been offered to elucidate this mechanism, among which should be mentioned the concentration speck theory of Sheppard, Trivelli, and Wightman, according to which the energy falling on the whole crystal is concentrated at a boundary between the silver sulfide specks and the silver bromide and there effects liberation of metallic silver by the release of bromine atoms.

Recently Toy and Trivelli have called attention to the importance of the photoconductivity effect; that is, the increase of the conductivity of silver halide when exposed to light, which, linked with the production of photopotential under the influence of light, may possibly develop a complete mechanism for the exposure of the photographic material.

The photoelectric phenomena associated with exposure are also being studied by the use of layers of silver halide on silver plates free from gelatin. These when exposed to light produce a potential first in one direction and then in the opposite, the explanation offered being that the first potential corresponds to the release of electrons from the silver bromide which reach the silver plate and charge it

negatively, these being followed by the slower moving bromine atoms which are positively charged.

Turning from exposure to development, the idea that the latent image acts as a nucleus for development has for many years been accepted as the basis for theories of photographic development, and the development reaction itself can be dealt with as a problem in chemical dynamics, it being treated as a heterogeneous reaction involving the solution, reduction, and deposition of the solid silver bromide by the developer.

The chemical reactions which the developer itself undergoes are very complicated in the case of the organic developers. A very simple development reaction is that which occurs with the ferrous oxalate developer, and this may perhaps be taken as the prototype for photographic development. Ferrous oxalate, which is insoluble in water, dissolves in potassium oxalate to form a red solution of potassium ferro-oxalate. This reacts with silver bromide, reducing it to metallic silver, and produces potassium ferri-oxalate and potassium bromide. The reaction can be represented by the following equation:

$$K_2Fe(C_2O_4)_2 + K_2C_2O_4 + AgBr \leftrightarrows K_3Fe(C_2O_4)_3 + KBr + Ag$$

If the developed image is treated with a solution of potassium ferri-oxalate and potassium bromide, the silver bromide is re-formed and this is, therefore, a simple reversible reaction.

When we deal with organic reducing compounds, the development reaction is very much complicated because these compounds will not reduce silver bromide when alone in solution, and their oxidation products react with the other necessary components of the solution. Thus, in one of the simplest cases, the oxidation product of hydroquinone, quinone, will react even with alkali, which must be present in order to permit hydroquinone to develop at all, while in the usual developer, containing both alkali and sulfite, the reactions are very complicated, the hydroquinone being eventually removed from activity by its transformation into hydroquinone sulfonates. In the case of the other developing agents—pyrogallol, paraminophenol, and its substituted derivatives—the chemistry of the reaction and the end products are not known at all.

The velocity of development is usually followed in photographic work as an increase of the H and D development factor γ; that is, the slope of the straight line portion of the characteristic curve.

This increases rapidly at first and then more slowly until it reaches a limit, which is known as "γ_∞," corresponding of course to a limit of density which can be developed for a single exposure, D_∞ (Figure 3). The relation between γ and time of development is an exponential one and can be represented approximately by the usual equation of the first order, so that the progress of development can be stated in terms of two factors: $\gamma_t = \gamma_\infty(1 - e^{-kt})$, γ_∞, the limit to which development can be carried, and K, the velocity constant of development. Thus, with the practical developers used, this simple

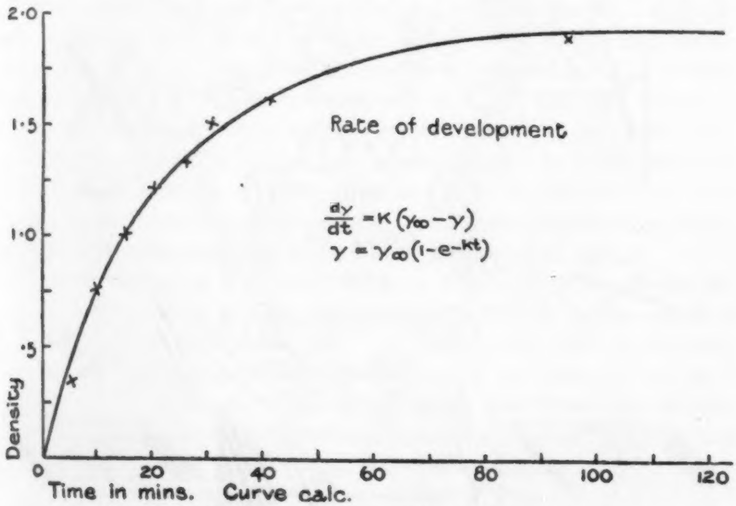

FIG. 3.—INCREASE OF γ WITH TIME OF DEVELOPMENT.

equation does not hold perfectly and various closer approximations are employed to represent the facts with the organic developing agents.

Turning to the study of the final image produced as a representation of natural objects, when a photograph of a natural object is made, the form can be represented only by differences in brightness. The accuracy with which the form is represented depends upon the precision with which the tones of the original subject are reproduced, and this subject, generally known as "the theory of tone reproduction," is fundamental to every photographic application. Psychologically, it is the apparent brightness which is of importance, but this can conveniently be treated as the physical brightness modi-

fied and interpreted by the eye and brain, and since it can be shown that throughout a wide range the apparent brightness is proportional to the physical brightness, it is usually sufficient in photography for tone reproduction to deal with the physical tones in the original and the reproduction.

The cycle involved in tone reproduction is illustrated in Figure 4. In the right-top corner, the object, in the form of a cross, is supposed

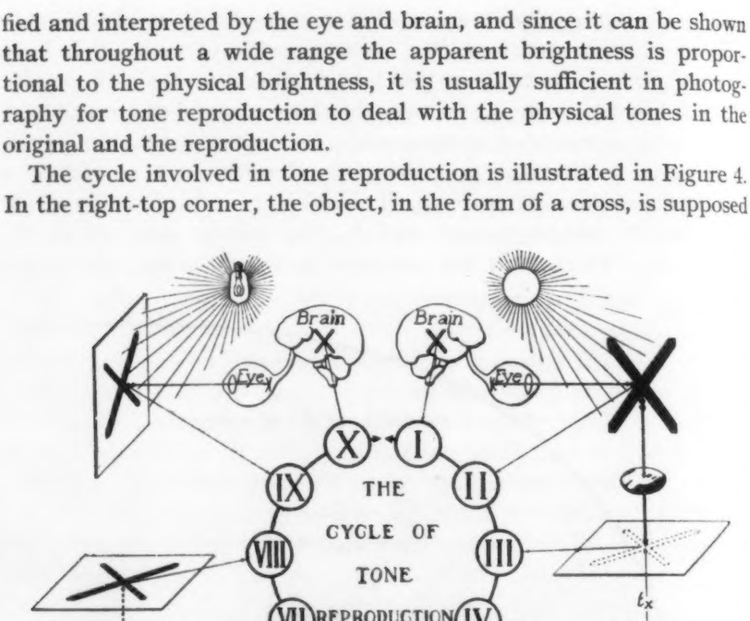

FIG. 4.—CYCLE OF TONE REPRODUCTION.

to be illuminated by sunlight and is viewed by an eye the image in which is conveyed to the brain and there produces a subjective impression corresponding to the objective image on the retina. An image of the object is projected by means of a lens on to the sensitive material which, after chemical treatment, gives a silver image (a negative), corresponding to the various degrees of brightness in the original object. This negative is then printed upon the positive material, which, after similar treatment, gives a positive which is viewed usually at a brightness level different from that by which

the original object was viewed and produces again a subjective impression. The whole cycle of tone reproduction is expressed by the relation of the subjective impression produced by the positive print to the subjective impression produced by the original object, but in practice it is sufficient to compare the objective print with the objective original.

The brightness differences which occur in nature may be due to differences in either the reflecting power of the various portions of the subject or the illumination. Since in natural scenes both the reflecting power and the illumination vary—some parts of a landscape consisting of clouds in sunlight and others of dark rocks in the shade—the range of contrast is often very considerable. For photographic purposes a scale or contrast of 1 to 4, in which the brightest thing is only four times as bright as the darkest, is very low, and such a subject would be called flat; a contrast of 1 to 10 is a medium soft contrast; 1 to 20, a strong contrast; 1 to 40, very strong; and 1 to 100 an extreme degree of contrast. All these degrees of contrast, for instance, occur in landscapes, street, and seashore scenes.

When an image of a natural object is produced in a camera, the relative brightnesses of the various tones will not be the same as those which were observed by the eye because the light in traveling from the object to the sensitive material in the camera will have suffered a certain degree of scattering which will affect the distribution of brightness among the various tones of the image. There may be some scattering in the air, and there will certainly be a good deal of diffuse light produced by the lens system. This will tend to lower the contrast in the image as compared with that of the original.

In the making of the negative, the reproduction of tone will depend upon the characteristic curve of the photographic material, as shown in Figure 2. If the exposure is so arranged that all the tones of the original subject fall on the straight line portion of this curve, the inverse reproduction in the negative will be proportional, and if, in addition to this, development is so arranged that the negative has a γ, that is, slope of the straight line, of unity, then the reproduction will be correct. In the print also, it is necessary that γ should be unity, or, if the γ of the printing material is not unity, it is necessary that the γ of the negative should be modified suitably, so that $\gamma_{neg.} \times \gamma_{pos.} = I$.

The last step in the making of a photograph is the printing of the negative, and where the print is to be viewed by reflected light it is

this step which introduces the largest amount of distortion in the reproduction of the tones. As is seen in Figure 5, the straight-line portion of a paper curve is usually short, and it is necessary in printing, moreover, to utilize at least the under-exposed portion of the paper curve. In making a paper print, therefore, the tone values are always distorted to some extent, especially those in the highlights corresponding to the under-exposure portion of the paper curve, only the portion of the picture falling on the straight-line portion of the characteristic curve of the paper being correctly rendered.

The computation of the tone reproduction in any photographic

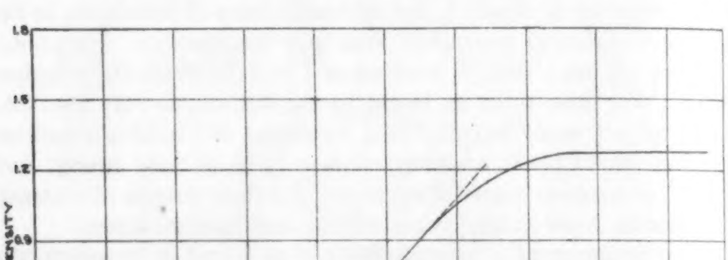

FIG. 5.—CHARACTERISTIC CURVE OF A PHOTOGRAPHING PRINTING PAPER.

operation is of great importance, especially in the applications of photography, such as processes of color photography or the reproduction of sound. This computation can be performed by means of graphic diagrams incorporating the characteristic curves of the negative and positive materials, and it is possible, therefore, to follow the whole process of the reproduction of tone in photography from the brightnesses of the original object to the distribution of light and shade in the finished print.

In scientific work the physical nature of the developed photographic image is often of considerable importance. As has been explained, the image is granular in structure, and its sharpness depends upon the structure both of the developed image and also

of the sensitive emulsion. The sharpness of the image may be expressed as the "density gradient at the edge." Suppose that a sharp knife edge be placed upon the emulsion and a collimated beam of light be allowed to fall normally upon the emulsion surface. Then after development the density at various distances from the edge may be measured with a microphotometer. If the density be then plotted as a function of the distance into the geometric shadow of the edge, the resultant curve may be termed the "sharpness curve," the sharpness being the angle of the straight-line portion of this curve (Figure 6). Two functions of the emulsion influence the form of this curve: one is the spreading of light into the emulsion, which depends upon the reflection and refraction by the crystals of silver halide and on their absorption of the light; the amount of this spreading can be computed. This effect is known as the "turbidity" of the emulsion, and it is measured by the increase in the width of an image of a slit. The increase of the width of such a slit is proportional to the logarithm of the exposure, and the constant of proportionality, termed by Ross the "astro-gamma," is a measure of the turbidity. The other factor in sharpness is the development factor; that is, the slope of the characteristic curve, but the development factor at the edge of an image is not identical with that for a large area owing to the great variation in the development reaction in such a case over very short distances. Since the turbidity and absorption of an emulsion vary with the wave length, the sharpness curve also varies with the wave length.

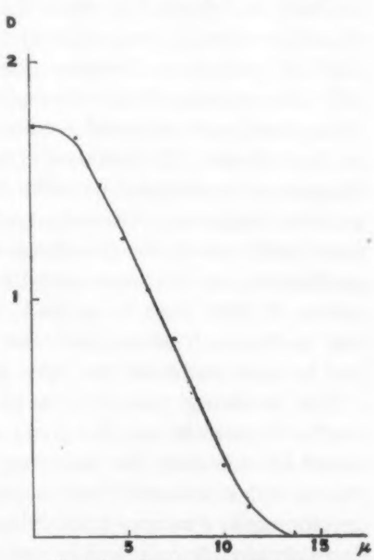

FIG. 6.—SHARPNESS CURVE.

Since the developed photographic image has a grain structure, it follows that under magnification any image must appear broken up to an extent depending on the size and arrangement of the grains. There are three phases in the inhomogeneity of a photographic deposit: (1) graininess due to the existence of the individual particles

of silver; (2) graininess due to clumping of these particles, and (3) graininess due to the agglomeration of the clumps. It should be understood that these phases are not separated by any distinct line of demarcation but merge by imperceptible gradations into each other. The impression of graininess is the result not only of the size of the grains of which the deposit is composed but also of their distribution and arrangement in groupings of various kinds.

The graininess may be measured and specified numerically, the method used depending upon the assumption that the graininess of a deposit is directly proportional to the distance at which the appearance of graininess becomes just imperceptible, provided that all other factors upon which depends the ability of the eye to distinguish homogeneity are constant. In order to avoid errors due to differences in the criterion, the distance at which the graininess to be measured disappears is compared with the distance at which structures of known periods disappear. Cross-line screens are chosen as the fixed structures with which the graininess is to be compared, so that a given graininess may be expressed by saying that it is equivalent to a screen of 3000 lines to an inch, it being implied by this that a 3000 line to the inch screen and the graininess in question would both just become visible at the same magnification.

The resolving power of a photographic material is a complex matter dependent on the sharpness and on the graininess, and as would be expected, the resolving power is not a fixed constant for a photographic material but is dependent both on exposure and on development, a range of resolving powers from 40 to 80 being sometimes obtainable by modification of development and exposure, which affect all three factors: the penetration of the light, the development factor, and the graininess, which enter into the determination of resolving power.

The resolving power is best determined practically by photographing narrow lines close together and observing the closeness of the lines which can just be resolved. Laboratory tests of photographic resolving power, however, cannot be applied directly without correction to physical measurements. In laboratory tests the contrast between light and shade in the detail is very high and the optical system is arranged to enable this high contrast to be obtained. In astronomical work the contrasts in fine detail are not nearly so great, and very often the resolving power of the optical system, including the atmosphere, is of the same order as that of the photo-

graphic material. Under these conditions the resolving power of the material is greatly diminished because of the low contrast of the object photographed. In spectroscopy the theoretical resolving powers are more likely to be applicable for bright line emission spectra, but in absorption spectra and to some extent in emission spectra the resolving power must be measured for the experimental conditions obtaining. The resolving power is of course dependent on the wave length.

The light-sensitive compounds of silver are sensitive primarily to radiation of wave lengths less than 500 mμ, and their sensitiveness to the longer wave lengths of the spectrum is exceedingly slight. As early as 1873, however, it was discovered by Vogel that sensitivity to longer wave lengths could be conferred by the treatment of the emulsion with certain dyes. Since that time the use of dyes for sensitizing photographic materials has extended very greatly, so that a large proportion of all photographs are taken upon materials which are sensitive in some degree to the whole of the visible spectrum, the use of "panchromatic" film, as it is termed, being almost universal in the motion picture industry.

Until recently, the so-called "orthochromatic" materials were sensitized only for the yellow-green region of the spectrum, in addition to their normal sensitiveness for the shorter wave lengths, obtained by the addition of erythrosine to the emulsion. The introduction of the polymethine dyes has made it possible without difficulty to prepare materials sensitive to the whole of the visible spectrum, their sensitiveness to red and green being *only slightly* inferior to the sensitiveness to the blue-violet. Since the eye is very insensitive to the blue-violet in comparison with its sensitivity for the green and orange, in order to get orthochromatic reproduction it is necessary to use a yellow filter to diminish the amount of the blue light forming the image, and in this way, colored objects may be reproduced so that the relative intensities are directly comparable with those seen by the eye.

The very high sensitiveness now available throughout the spectrum eliminates any difficulty in making photographs by selected light corresponding to any spectral region, and a large number of light filters are employed for this purpose in photographic work. In color photography and in special work, such as photography from the air, it is quite feasible to take exposures of very short duration by means of pure red or green light, and the photography of spectra, even of

stellar spectra, throughout the visible spectrum presents no difficulties.

There are a few dyes whose absorption bands and sensitizing power lie in the extreme red or even in the infra-red beyond the visible spectrum. Kryptocyanine, a dye discovered by Adams and Haller in 1919, enables photography to be done without difficulty in the spectral region between 700 and 800 mμ, and very interesting photographs have been made by its use. In landscapes photographed by light of this wave length, for instance, the blue sky appears almost black, since very little radiation of this wave length is scattered by the sky, and the high reflecting power of chlorophyll in this region

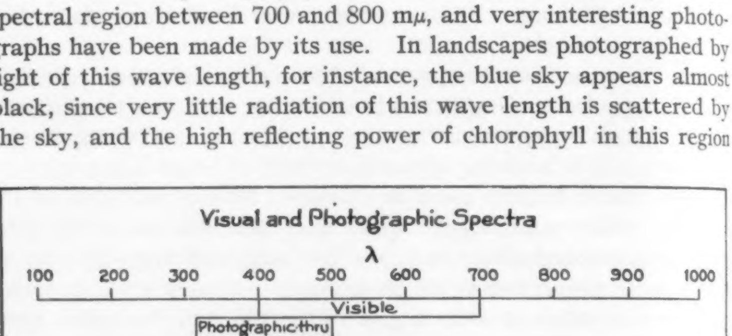

FIG. 7.—EXTENSION OF SPECTRUM.

makes foliage appear white. These phenomena were pointed out by R. W. Wood more than twenty-five years ago. W. H. Wright and others have used kryptocyanine in their studies of the surface of the planets, and A. W. Stevens while on an expedition for the National Geographic Society has succeeded in making aerial photographs with an exposure as short as $^1/_{50}$ of a second from very high levels; he obtained a satisfactory photograph of the peaks of the Andes range at a distance of over 300 miles, the penetration of the atmosphere by light being proportional to the fourth power of the wave length and therefore very great for the extreme red.

For the infra-red beyond 800 mμ, which is of great interest to spectroscopists, neocyanine, a dye obtained originally as a by-product in the synthesis of kryptocyanine, has proved very valuable, its

normal spectral sensitiveness extending to 900 mμ, while by hypersensitizing and the use of long exposures, the infrared line of mercury at 1014 mμ may be photographed without difficulty. Using this dye, Babcock has pushed the photography of the solar spectrum to 1163 mμ. The extension which has been achieved in the photography of the spectrum is illustrated in Figure 7. New work in this field is proceeding continually but is slow and difficult.

The measurement of the color sensitiveness of photographic materials can be accomplished either sensitometrically or by means of a spectrograph. A simple grating spectrograph using a tungsten lamp as the source and a wave length scale held in front of the plate so that it is impressed upon it at the time of photographing a spectrum is all that is required, but it is convenient to have a sector or a neutral tinted wedge in front of the slit by means of which a curve of the sensitiveness of the material is drawn automatically so that the position of the sensitive bands can be seen at a glance. For quantitative measurements a more convenient method of determining the sensitiveness is to give a graduated series of exposures through color filters transmitting known regions of the spectrum. For this purpose exposures are usually made through the standard set of tricolor filters used for color photography, each of them transmitting approximately one-third of the visible spectrum, their colors being orange-red, green, and blue-violet. The characteristic curves obtained through these filters are usually of slightly different shapes and are rarely strictly parallel to one another, so that the sensitometric characteristics of a photographic material are dependent upon the wave length of the radiation producing an image. No general principles can be laid down as to the variation of gradation with wave length, the effect depending upon the particular emulsion and sensitizing dyes which have been employed.

One of the most important applications of photography in science is to photometry, and no account of the science of photography would be complete without some mention of the photographic methods of photometry.

These methods can be divided into two classes: (1) those dependent on the increase in size of an image with increasing intensity or exposure time; (2) those dependent upon the increase of the density produced in an area of some size. The first method is that used by astronomers in what is known as the "focal method of the photometry of stars," the diameter of the star image being measured.

When an artificial star is photographed in the laboratory with a series of increasing exposures, it is found that the relation between the diameter of the image d and the exposure is of the form

$$d = a + b \log E,$$

this formula applying with considerable accuracy through a range of exposures of one to several hundred. Over the very wide range of intensities used in stellar magnitude determinations, however, the astronomers have preferred to use the formula

$$\sqrt{d} = a + b \log I$$

which fits the measurements better for greater diameters of the image, though for images of the smallest diameters it does not fit so well as the first formula. The value of the constants a and b is determined on plates exposed to stars of known magnitudes, the unknown stars being interpolated upon the curve. This method of photometry, which depends upon the diameter of the image, is very valuable in astronomy but of little use in other branches of physics, its application even in spectroscopy being prevented by the varying width and sharpness of spectral lines.

For most physical purposes it is necessary to use measurements depending upon the density of the image produced, these densities being then interpolated on a scale of densities produced by known exposures. It is obvious that the accuracy of photometric measurements made in this way will depend upon the production of the scale of densities by known exposures under conditions which are exactly the same as those under which the densities to be measured are produced. We must eliminate, (1) variations owing to the material; *i. e.*, irregularities in sensitiveness, thickness of coating, etc.; (2) variations owing to the treatment; *i. e.*, differences in developing the intensity scale and the densities to be measured; (3) variations in the intensity or time of exposure of the two scales (it is not justifiable to assume that time and intensity, the two components of exposure, are reciprocally equivalent); (4) variations owing to the quality of the light. The scale must be made by light of the same wave length as that which produced the exposures to be measured. Provided that these precautions are taken, the methods of photographic photometry are capable of giving results of very satisfactory accuracy while the convenience of the method is unquestionable.

A—Landscape Picture Showing the Brightness of Various Portions of the Scene as Measured by a Photometer and Recorder in Meter-Candles.

B—Landscape Photographed by Blue Light.

C—Landscape Photographed by Infra-Red Light Using a Kryptocyanine Plate.

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The application of photographic methods in scientific research will undoubtedly continue to increase and will be of greater value if at the same time a knowledge of the science of photography becomes more widely diffused, since only by that knowledge can photographic methods be most efficiently applied.

EDITORIAL COMMENTS

The Cleveland convention, our thirty-first, was a banner convention of the Society. Forty-five of the fifty-five institutional chapters were represented, and thirteen of the twenty-eight clubs. Four chapters had appointed delegates who were not recorded as voting.

Since the convention, the secretary has received from many of the delegates some splendid suggestions regarding the conduct of the society's business and the program of our Annual meetings. These will all be presented to the Executive Committee at its annual Spring meeting. The more suggestions presented, the greater the satisfaction of the National Officers, who sincerely desire and urge this participation in the society's affairs by all our chapters. Sigma Xi is expanding in healthy way both in size and influence. Progress is sure and substantial when our entire membership gives thought to our problems and communicates ideas and recommendations to the national officers.

Will all chapters, through their officers, make comments and suggestions to the national secretary for presentation to the Executive Committee? They will be gratefully received.

The record of attendance at conventions since 1925 is as follows:

Chapters Represented

1925, Kansas City, 23 of the 42 chapters, 54.7%
1926, Philadelphia, 24 of the 45 chapters, 53.3%
1927, Nashville, 27 of the 46 chapters, 58.7%
1928, New York, 31 of the 50 chapters, 62.0%
1929, Des Moines, 36 of the 50 chapters, 72.0%
1930, Cleveland, 45 of the 55 chapters, 82.0%

Clubs Represented

1925, Kansas City, 9 of the 13 clubs, 69.2%
1926, Philadelphia, 4 of the 15 clubs, 26.6%
1927, Nashville, 6 of the 15 clubs, 40.0%
1928, New York, 5 of the 17 clubs, 29.8%
1929, Des Moines, 12 of the 22 clubs, 54.5%
1930, Cleveland, 13 of the 28 clubs, 46.4%

The following table shows in detail how the attendance at the last six conventions was distributed among the chapters.

OFFICIAL DELEGATES AT THE LAST SIX CONVENTIONS

Chapter	1925	1926	1927	1928	1929	1930
Cornell	1	1	2	3	1	2
Rensselaer	1		(1)*	1		1
Union		2	1	(2)*	1	1
Kansas	2		1	2	2	3
Yale	1	1	1	2	1	1
Minnesota		1	1	1	3	1
Nebraska	1	1	2	1	3	3
Ohio		1	1		2	1
Pennsylvania	2	2	2	2	2	2
Brown		1			1	1
Iowa	1	1	1	1	1	1
Stanford	1		1	1	1	
California			1		1	1
Columbia	1	1		1	1	1
Chicago	2	1	1	1	3	2
Michigan	1		2			1
Illinois	2	1	2	2	2	1
Case		1	1	2		1
Indiana	2	1	3		2	1
Missouri	1		1		3	2
Colorado	1		(1)*	(1*)	2	2
Northwestern		2	1	1	3	
Syracuse		1	1		1	2
Wisconsin		1	(1)*	1	3	
University of Washington	1		1			1
Worcester			1			
Purdue	1		1	1	2	(1)*
Washington University	1		(1)*	1	3	1
District of Columbia						
Texas	2		1	2		
Mayo Foundation	1		(1)*	1	2	1
North Carolina				1		
North Dakota	1	1			1	(1)*
Iowa State College (Ames)		1		1	3	
Rutgers		1		1		2
McGill			1			1
Kentucky	1			2	1	1
Idaho				1		
Swarthmore		2	(1)*	2	1	2
Oregon				1	1	1
Virginia	2	2	1	(2)*		1
Johns Hopkins		1			3	1
Calif. Inst. of Technology					1	
New York University (as club)	1		(1)*	1	(1)*	1

* Delegates reported as appointed, but not reported voting at convention.

OFFICIAL DELEGATES AT THE LAST SIX CONVENTIONS (*Contd.*)

Chapter	1925	1926	1927	1928	1929	1930
Univ. of Cincinnati			(3)*		(1)*	1
Michigan State College (as club)	1		1	1	2	(1)*
Arizona (as club)	2			2	1	(1)*
Lehigh				2	1	2
Maryland				2	(3)*	
Kansas State College (as club)	1	1	2		3	2
Coll. of Med. of U. of Illinois				1	1	1
Pennsylvania State College						1
Oklahoma (as club)	2	3	2		2	1
State Coll. of Washington (as club)	1		1	1	1	1
Wyoming (as club)			1		1	1
Rochester (as club)				1		1

SIGMA XI CLUBS AT THE LAST SIX CONVENTIONS

Name	1925	1926	1927	1928	1929	1930
Southern California					1	
Duluth						
Carleton College	1			1	1	1
University of Denver	1					1
Oregon State Agr. College					1	
West Virginia University			1		1	1
University of Maine				3	1	
University of Pittsburgh		1		1		1
University of Wyoming			1		1	
University of Florida	1	1	2		1	1
University of Rochester				1		
Colo. Agricultural College					1	1
State College of Washington	1		1	1	1	
Univ. of South Dakota					1	
Louisiana State University					1	
University of Alabama						
Univ. of California at Davis					1	1
Univ. of Utah						
Clark University						
St. Louis University						1
Oklahoma A. and M. College						1
Miami University						1
University of Georgia						1
University of Buffalo						1
Bucknell University						1

MINUTES OF THE MEETING OF THE EXECUTIVE COMMITTEE OF SIGMA XI, CLEVELAND, DECEMBER 30, 1930

The second meeting of the Executive Committee for 1930 was held in Room 34, Main Building, Western Reserve University, December 30, 1930. The meeting was called to order at 2:00 P.M. by President Stewart. Those present were: President Stewart, Secretary Ellery, Treasurer Pegram, Dr. Wilson, Professor Lloyd, and Professor Cole.

1. FORMAL PETITION:

A.—*Harvard University:*

A formal printed petition for a chapter was presented from a group at Harvard University. It was

Voted—To present the petition to the Convention with the recommendation to favorable action.

2. REPORT FROM OFFICIAL VISITOR:

Professor Cole presented a report of his visit as "official visitor" to the Western Reserve University, as follows:

December 30, 1930

To the Executive Committee,
The Society of Sigma Xi

Gentlemen:

In accordance with the instructions of this committee at its meeting in Washington last spring, I this summer gathered as much information as I could relative to research conditions at Western Reserve University. Opportunity to do this was facilitated by my residence in the institution during the summer session.

As in a number of the older colleges, the traditions in Adelbert College have in the past been largely dominated by its classical spirit and science is still looked upon by a few of the classical group as a pernicious interloper. In spite of this, there have been men devoted to research in the science departments and there has been a steady development of scientific work. This permeates strongly today such departments as chemistry, physics, biology, and geology.

In the professional schools much outstanding research is progressing as a regular part of their activities. The same applies also, of course, to the Case School of Applied Science.

While such branches as the College for Women and Cleveland College tend somewhat to dilute the research atmosphere, the attitude of President Vinson and Dean Benton of the graduate school are distinctly sympathetic to high scholarship and research, and there is a definite attempt to see that the men qualified for research have their teaching burdens lightened to allow them time for it.

In my mind the conditions at Western Reserve are highly satisfactory for a chapter of Sigma Xi and my recommendation is that their petition should be acted upon favorably.

Respectfully submitted,

L. J. Cole

After discussion, it was

Voted—To request the petitioning group at the Western Reserve University to present a formal printed petition for the consideration of the Committee at its next meeting.

3. Informal Petitions:

A.—*Princeton University:*

An informal inquiry regarding a chapter was presented from a group at Princeton University. After discussion, it was

Voted—To request the petitioning group at Princeton University to present a formal printed petition for the consideration of the Committee at its next meeting.

B.—Informal inquiries and petitions from groups at six institutions were received and discussed. All were referred to sub-committees for study and report at the Spring Meeting.

4. Amendment to the Constitution:

The Cornell Chapter proposed that Article III, Section 3, of the Constitution be amended to read as follows:

Section 3. Eligibility: Members. The following, and no others, are eligible to election as members in a chapter at any institution: (*a*) any person of professorial or equivalent rank in the institution who has shown noteworthy achievement as an original investigator in some branch of pure or applied science: (*b*) any staff member of lesser rank, or any student in the institution who, as judged by his actual work of investigation, has exhibited an aptitude for scientific research.

After discussion, it was

Voted—To ask the Cornell delegates to the Convention to explain further the purpose and the meaning of the proposed amendment.

5. COMMITTEE ON AWARD OF RESEARCH GRANTS:

At the meeting of the Committee, held in Washington, April 28, 1930, it was voted to ask the President to make recommendations at the December meeting regarding the personnel of the Committee of Award of Research Grants. The president presented his report and it was

Voted—That the Committee of Award of Research Grants be appointed annually by the President after nominations by the Chairman of the retiring committee and the National Secretary of the Society.

6. INSTALLATION OFFICERS:

It was

Voted—That it is the duty of the President of the Society to act as the installing officer in the case of each new Chapter; that in case it is impractical for the President to serve he shall designate the installing officer; that, further, it is desirable that the Secretary of the Society shall assist the President at each installation, unless the expense thereby incurred is excessive.

7. INSTRUCTIONS FOR OFFICIAL VISITORS AND INSTALLATION OFFICERS:

It was

Voted—That the Secretary be asked to present to the members of the Executive Committee for their suggestions and recommendations, a proposed pamphlet for the guidance of official visitors and installing officers.

8. THE SPRING MEETING OF THE EXECUTIVE COMMITTEE:

It was

Voted—That the Secretary ask members of the Committee to name dates of a Spring Meeting which would best suit their convenience.

9. ADJOURNMENT:

The meeting adjourned at 3:50 P.M.

EDWARD ELLERY, *Secretary*

PROCEEDINGS OF THE THIRTY-FIRST CONVENTION OF THE SIGMA XI

The Thirty-first Convention of the Society of the Sigma Xi was held in Room 34, Main Building, Western Reserve University, December 30, 1930.

1. CALL TO ORDER:

President Stewart called the business session to order at 4:00 P.M. and appointed the Committee on Credentials as follows:

Professor J. W. Buchta, Minnesota, *Chairman*
Dr. Buford J. Johnson, Johns Hopkins
Dr. Lewis J. Stadler, Missouri

2. REPORT OF COMMITTEE ON CREDENTIALS:

The Committee received the credentials of delegates and reported the following chapters and clubs represented:

CHAPTERS

Cornell	F. K. Richtmyer
	C. F. Curtis
Rensselaer	R. A. Patterson
Union	V. Rojansky
Kansas	H. M. Huford
	P. B. Lawson
	W. J. Baumgartner
Yale	W. R. Langley
Minnesota	J. W. Buchta
Nebraska	R. W. Goss
	M. H. Swenk
	C. C. Camp
Ohio	F. A. Hitchcock
Pennsylvania	C. E. McClung
	D. H. Wenrich
Brown	A. D. Mead
Iowa	Walter A. Loehwing
Stanford	
California	H. Kirby, Jr.
Columbia	G. B. Pegram
Chicago	A. E. Emerson
	H. C. Cowles
Michigan	Alfred H. Stockard
Illinois	W. P. Hayes

Case	K. H. Donaldson
Indiana	N. E. Hubbard
Missouri	Lewis J. Stadler
	Charles W. Greene
Colorado	E. D. Crabb
	W. B. Pietenpol
Northwestern	
Syracuse	D. P. Randall
	H. F. A. Meier
Wisconsin	
University of Washington	G. B. Rigg
Worcester	
Purdue	R. G. Dukes*
Washington University	E. S. Reynolds
District of Columbia	
Mayo Foundation	Louis B. Wilson
North Carolina	
North Dakota	E. A. Baird*
Iowa State College	
Rutgers University	A. A. Boyden
	J. W. Shive
McGill	F. E. Lloyd
Kentucky	M. N. States
Idaho	
Swarthmore	H. J. Creighton
	Winthrop Wright
Oregon	L. Friedman
Virginia	J. E. Kindred
Johns Hopkins	Buford Johnson
California Institute of Technology	
New York University	H. W. Stunkard
Univ. of Cincinnati	O. T. Wilson
Michigan State College	V. R. Gardner*
Arizona	E. F. Carpenter*
Lehigh	C. A. Shook
	P. L. Bayley
Maryland	
Kansas State College	Roger C. Smith
	F. C. Gates
College of Medicine	
University of Illinois	William H. Welker
Pennsylvania State College	Frederick W. Owens
Oklahoma	H. W. Dodge
State College of Washington	E. W. Webster
Wyoming	Aven Nelson
Rochester	T. R. Wilkins

* Not recorded as voting.

Clubs

University of Pittsburgh	O. Blackwood R. T. Hance D. Hooker
Oklahoma A. & M. College	J. C. Ireland
Miami University	Orton K. Stark
Carleton College	R. H. Waggener
University of Georgia	A. S. Edwards
University of California at Davis	F. J. Veilmeyer
University of West Virginia	C. R. Orton
University of Florida	G. E. Weber
University of Buffalo	E. J. Moore
St. Louis University School of Medicine	James B. Macelwane
University of Denver	R. E. Nyswander E. B. Renaud
Bucknell University	W. H. Eyster
Connecticut Agricultural College	Dewey G. Steele

The following officers were present:

President: G. W. Stewart, Iowa
Secretary: Edward Ellery, Union
Treasurer: George B. Pegram, Columbia
Executive Committee: Louis B. Wilson, Mayo Foundation
F. E. Lloyd, McGill
Leon J. Cole, Wisconsin
Alumni Committee: Donald H. Sweet, Chicago

3. Minutes of Proceedings of the 30th Convention:

The account of the proceedings of the 30th Convention of the Society at Des Moines, December 28, 1929—published in the March, 1930, Quarterly—was approved as printed.

4. Report of President:

President Stewart gave his annual report. (See page 33—this issue.)

5. Report of Secretary:

The annual report of the Secretary was presented. (See page 38 this issue.)

6. Report of Treasurer:

The Treasurer offered his annual report which was referred to an Auditing Committee consisting of Mr. John T. Finneran, Cashier, and Miss Lorraine Brett, of the bursar's office of Columbia University. (See page 41—this issue.)

7. New Business:

A.—*Petitions for Charters:*

The President, on behalf of the Executive Committee, presented printed petitions for charters for chapters from groups at the following institutions:

University of Pittsburgh
Harvard University

The President stated that each of these petitions had been under consideration by the Executive Committee for some time and that the Committee recommended favorable action by the Convention. Upon roll-call of the chapters, the vote of the Convention was unanimous in favor of granting the petition in each case.

B.—*Committee on Nominations:*

The President announced that he had appointed the following as a Committee on Nominations:

Professor F. K. Richtmyer, Cornell, *Chairman*
Professor C. E. McClung, Pennsylvania
Dr. Vernon Kellogg, National Research Council

The report of the Committee was called for. Professor Richtmyer reported for the Committee as follows:

For member of the Executive Committee to serve five years:

Professor Rodney H. True, Pennsylvania

For member of the Alumni Committee to serve five years:

Dr. F. B. Utley (Yale), Pittsburgh

It was

Voted—That the report of the Nominating Committee be adopted and that the Secretary be empowered to cast a ballot for the officers named.

The Secretary announced that the ballot had been cast and the President declared the officers duly elected.

C. *Conservation of Research Talent:*

Acting upon a recommendation in the annual report of the President, it was

Voted—That the Executive Committee be requested to give early consideration to the question of research in colleges, making use of studies already conducted by other bodies, and to recommend to

the next annual Convention appropriate policies for the development and conservation of research talent in our educational institutions.

Subsequent to the Convention, President Stewart appointed the following committee to make the proposed study and recommendations:

Professor G. A. Baitsell
Professor G. B. Pegram
Professor G. W. Stewart

D. *Amendment of the Constitution:*

The Cornell Chapter offered the following amendment of the Constitution:

Be it resolved, that Article III, Section 3, be amended to read as follows:

> Section 3. Eligibility: Members. The following, and no others, are eligible to election as members in a chapter at any institution: (*a*) any person of professorial or equivalent rank in the institution who has shown noteworthy achievement as an original investigator in some branch of pure or applied science; (*b*) any staff member of lesser rank, or any student in the institution who, as judged by his actual work of investigation, has exhibited an aptitude for scientific research.

Article III, Section 3, of the present Constitution reads as follows:

> Section 3. Eligibility: Members. The following, and no others, are eligible to election as members in a chapter at any institution: (*a*) any professor, instructor, or other member of the staff of the institution who has shown noteworthy achievement as an original investigator in some branch of pure or applied science; (*b*) any student in the institution who, as judged by his actual work of investigation, has exhibited an aptitude for scientific research.

After considerable discussion, it was

Voted—(*a*) That in the judgment of the Convention, the eligibility of an instructor to membership in the Society should be decided on the requirements named in (*b*) of Section 3, Article III, of the Constitution, as follows: "who, as judged by his actual work of investigation, has exhibited an aptitude for scientific

research." (*b*) That the proposed amendment be referred to the Executive Committee and the Cornell Chapter for re-wording. (*c*) That the re-phrased amendment be presented to the 1931 Convention.

E. *The Semi-Centennial:*

The Secretary announced that a sub-committee of the Executive Committee had begun the consideration of the celebration of the Semi-Centennial of Sigma Xi in 1936; that suggestions regarding the form of celebration were desired from all chapters; and that early in 1931 the national officers would communicate with chapter officers regarding this very important event.

F. *Federal Grant for Research:*

Professor Greene (Missouri) presented the following resolution:
To the Congress of the United States:

Whereas we are convinced that research in the fundamental sciences is a necessity for the maintenance and advancement of modern civilization;

Whereas, the Congress of the United States has recognized the principle of financial encouragement of teaching, research and the distribution of useful knowledge by several acts of appropriation.

We, the Society of Sigma Xi, respectfully submit to your consideration the importance of stimulating by financial aid to the states and territories, research in the fundamental and basic sciences, on the advances of which the welfare of the United States rests.

After discussion it was

Voted—That the resolution be referred to the Executive Committee for report at the 1931 Convention.

G. *Annual Assessment:*

Upon motion of the Treasurer, it was

Voted—That the usual assessment on the several chapters of $1.00 per enrolled member and associated be levied for 1931.

H. *Vote of Thanks to Local Committee:*

Upon motion of Professor Pegram, it was

Voted—That the Convention express its appreciation and thanks to Dean Focke and Professor Donaldson for their splendid assis-

tance in arranging for the annual meetings of the Society at Cleveland.

8. Adjournment:

The convention adjourned at 5:30 p.m. for the Annual Dinner.

Edward Ellery, *Secretary*

Annual Dinner

The Annual Dinner of the Society was given in the Cleveland Club at 6:30 p.m. The Society had as guests the American Physical Society; its president, Professor Henry G. Gale, of the University of Chicago; the retiring president of the A. A. A. S., Professor R. A. Millikan; Dr. C. E. K. Mees, Director of Research and Development of the Eastman Kodak Company; and President Wickenden of the Case School of Applied Science. About three hundred members, associates and guests were present. The dinner was held in the Ball Room of the Cleveland Club, and arrangements for it had been admirably made by Professor Donaldson, of the Case School, and a member of the Club.

The dinner was followed by the Ninth Annual Sigma Xi Address, given by Dr. C. E. K. Mees, in the Auditorium of the John Hay High School, on the topic: "The Science of Photography." The address is printed in full as the leading article in this issue of the Quarterly.

REPORT OF THE PRESIDENT FOR THE YEAR 1930

The President's report is by custom a résumé of the items representing the progress of the Society as an organization. Your President has taken advantage of the opportunity by presenting, in addition, a definite recommendation for your consideration.

The Executive Committee held its annual Spring meeting in Washington in April. All members but one were present.

The following items were considered:

1. A formal printed petition for a chapter was presented from a group of petitioners at the University of Pittsburgh. The Executive Committee voted to present the petition to the Cleveland Convention, accompanied by a recommendation to favorable action.

2. Announcement was made that several members of the faculty at Harvard University were contemplating a petition for a chapter at Harvard. The Executive Committee appointed a sub-committee with power, consisting of the president and secretary, to arrange for the reception of the petition when and if made. The result is the formal printed petition presented at the Cleveland meeting.

3. An informal petition containing full information about research facilities and qualifications of faculty members of one institution was received, and upon consideration the Committee voted to send an official visitor to the institution for the purpose of interviewing administrative officials and members of the faculty, and making a general survey of the equipment. That official visitor has made a report which the Executive Committee is now considering with reference to possible further action.

4. Inquiries from nine different institutions with reference to a possible petition for a charter for a chapter were brought up for consideration. In one instance the Committee expressed distinct interest, but felt that it was not yet ready for definite action. In the eight other cases the Committee voted to recommend the organization of Sigma Xi clubs at the particular institutions.

5. During the year five new chapters have been installed as follows:

Pennsylvania State College
University of Oklahoma
State College of Washington

University of Wyoming
University of Rochester

and reports of the installation proceedings were published in the June issue of the QUARTERLY.

6. The Committee considered the matter of publishing a list of lecturers who would be available for addresses at various institutions under the auspices of the local chapters. Such a list appeared in the September issue of the QUARTERLY. It was compiled from suggestions made by officers of a number of our chapters.

7. The Committee considered the question of the content of the official journal, and the recommendation was adopted that the journal should contain addresses made at various chapters and papers on progress in different scientific fields. Acting upon that suggestion there have been published during the current year the following articles:

Professor Parker of Harvard—a paper on "Some Aspects of Human Biology."

Professor Cole of Wisconsin—a paper on "Heredity as We See It Today."

Professor Jackson of Minnesota—a paper on "What Is Science?"

Professor Lind of Minnesota—a paper on "Progress in Chemistry."

Papers on topics and progress in other fields of science are in prospect for the coming year.

8. The Committee had under consideration the resolution from the Cornell chapter which was first presented at the New York convention in 1928, and which read as follows:

"WHEREAS, It is not desirable at this time to attempt to define scientific research in terms of either method or subject matter,

Be it resolved, That noteworthy contribution to (or promise of notable accomplishment in) scientific investigation shall constitute eligibility for election as member (or associate) of Sigma Xi regardless of the field in which the candidate may be working. Each separate chapter shall be responsible for the interpretation of this principle in election of its membership or associateship."

The 1928 convention voted to lay the resolution on the table until the 1929 convention. At the 1929 convention the delegates voted to refer the question to the Executive Committee "with power to take such action as in its judgment would best serve the purposes of the Society." In accordance with that action of the 1929 con-

vention, the Executive Committee discussed the resolution at length and voted that the sciences listed in the March, 1928, issue of the QUARTERLY, namely: mathematics, physics, chemistry, astonomy, sciences of the earth, biology—in its various branches, including psychology, anthropology, medicine—in its various branches, engineering—in its various branches, and other allied thereto, represent in general the *fields* of investigation which it is the purpose of Sigma Xi to recognize; and that in case any chapter is in doubt regarding the eligibility of investigators, it should, before election takes place, ascertain and be guided by the opinion of the Executive Committee or one of its officers authorized by the Executive Committee to act for it in such matters. In this statement the word "fields of investigation" have been used rather than "department of investigation" to indicate the Society's interest in the subjects of investigation rather than in the exact form of organization in a university.

9. The Committee began consideration of a celebration of the semi-centennial of the Society, which is to be observed in 1936. A sub-committee, consisting of the president, secretary, and treasurer, Dr. Whitney, Professor Baitsell, and Mr. Davies, was appointed for the purpose of beginning the preparation of a program for that event. The sub-committee has had one meeting and considered tentatively many suggestions about a suitable celebration. Among other items considered by the sub-committee was the suggestion that all chapters take up the subject at some early meeting or meetings, and send to the national secretary their recommendations and suggestions regarding the semi-centennial. The event is important not only for the Society itself, but for the cause of research in general. Communications about it will be sent to chapter officers in the near future, and the consideration and active coöperation of all chapters is earnestly desired.

10. A sub-committee on the form of diploma presented a report of progress. It is felt by the Executive Committee and by many chapters that the time has come when the form of diploma involving a slight change in the constitutional requirement—and hence an amendment to the constitution—is on exhibit here at this convention.

11. The Executive Committee voted that it was not desirable to continue relations with the so-called Association of College Honor Societies with which Sigma Xi has been tentatively connected during the last three years. The ground for action is that although Sigma Xi does confer honors by election to membership, that function is

only one of many, all of which are primarily for the promotion of research. Consequently the Society cannot gain by membership in an association having a quite different emphasis.

12. It is now my purpose to present one recommendation directly to the Convention. It refers to the increase of our activities in the promotion of research. They now include the following policies:

1. Encouragement by election of members and by chapter activities—now a permanent policy.
2. Direct encouragement of research by financial support—now a permanent policy.
3. Maintaining and revising the interest of non-chapter members in research—now accomplished in part by the publication of the QUARTERLY and the securing of gifts.
4. Chapter activity in the awarding of research prizes and of funds for specific researches. Upon inquiry Secretary Ellery has found at least seven of our fifty-six chapters engaged in this activity, namely: California, Minnesota, North Dakota, Ohio, Oregon, Pennsylvania, and Virginia.

But we ought to recognize that as a national organization we should have an active interest in the conservation of research talent through the recognition and encouragement of such talent as early in the life of the individual as possible. We cannot exercise this interest merely through our chapters, for the higher educational institutions having chapters of our Society are but a fraction of the whole.

The Society of the Sigma Xi is the one national body that can undertake this in behalf of all sciences. It is obvious that the possibilities here involved extend into the undergraduate work of students in all colleges and universities. But one may surmise that it also inevitably and ultimately includes the attitude of mind and the abilities of teachers in college and probably secondary schools.

The promotion of research by active interest in individual talent is a very large prospect. In proposing to the Society that it emphasize this problem by an additional specific effort it is perhaps advisable not to hide the possible ultimate value of such a movement by the consideration of a few simple concrete beginnings. But it may be best to assure you that your president has in mind a fairly definite plan for the encouragement of research talent in every college within the borders of our Society including our own chapter institutions. This plan would involve action on the part of the Society as a whole,

and also voluntary action on the part of the chapters. The subject is clearly one in which the Society should take an active interest. I therefore recommend that the convention request the Executive Committee to give early consideration to this subject and recommend to the next annual convention additional policies with reference to the conservation of research talent. If the convention makes this request, your president will then assume the responsibility of appointing a sub-committee of the Executive Committee to report to that body in April.

G. W. STEWART, *President*

REPORT OF THE SECRETARY FOR THE YEAR 1930

Following is a statistical account of some of the activities of the Secretary's office during the calendar year 1930, with comments on some phases of the work:

1. MEMBERSHIP:

	1929	1930
A. Total Society	23,404	24,728

B. New Members:*

1. Members—786 (of which 106 are promoted from associates)
2. Associates—538

* See Section 2B for list of chapters which have not yet sent in cards.

C. Growth of chapters and clubs:

1929		1930	
Chapters, 51	Clubs, 22	Chapters, 56	Clubs, 27

2. FILES:

A. Geographical:

We now have our own addressing machine and are at work preparing stencils of our complete membership.

To date, Dec. 23, 1930, 2250 stencils have been made, requiring about 2 weeks time from our assistant.

This means that we shall be preparing our own wrappers for the Quarterly and making our own changes of address, thus saving considerable expense. It further means that the addressing machine will be used in the annual circularization of the Alumni, and in the frequent letters that must pass between the chapter secretaries and the national secretary.

The stencils will constitute our geographical file hereafter, and as rapidly as corrections are received in the office of the national secretary a new stencil will be prepared and filed. This simplifies the machinery of the office enormously, since heretofore we have not only had to correct addresses on the card files in the secretary's office, but also have had to make a separate list for transmission to the publishing house in Easton.

B. Chapter:

At the date this report was compiled (December 22), the following chapters had not submitted cards for their new members and associates for the current year:

California	District of Columbia
Columbia	McGill
Michigan	Kentucky
Illinois	Swarthmore
Indiana	Calif. Inst. of Tech.
Missouri	New York University
Colorado	Arizona

Syracuse	Lehigh
Wisconsin	College of Medicine, Univ. of Illinois
University of Washington	Pennsylvania State College
Washington University	

This is not so favorable a showing as in the Secretary's report for 1929, when only three chapters were reported as not having submitted chapter lists.

C. No Address:

By means of our lists of missing persons published quarterly in the official journal, and by means of checking the names in the Summarized Proceedings of the A. A. A. S., we have been able to reduce the file of missing persons from 2791 to approximately 2291.

3. QUARTERLY:	1929	1930
A. Total number of pages:	111	124
B. Circulation:	8000	9898
Distributed as follows:		
Alumni Contributors	883	
Independent Subscribers	6	
Chapter Members	9009	
Alumni new to Quarterly list	390	
Alumni lost to Quarterly list	25 (no address)	

C. Mailing lists not received from:

Cornell	Iowa State College
Kansas	McGill
Yale	Kentucky
Pennsylvania	Swarthmore
Columbia	Calif. Inst. of Tech.
Michigan	New York University
Indiana	Univ. of Cincinnati
Colorado	Michigan State College
Northwestern	Kansas State College
Syracuse	College of Medicine, Univ. of Illinois
Wisconsin	Pennsylvania State
University of Washington	Wyoming
District of Columbia	

4. ALUMNI MOVEMENT:

This year the work of circularizing alumni was done entirely through the secretary's office.

	1929	1930
Number of letters sent out	11,880	14,500
Number returned undeliverable	772	820
Number of alumni responding	929	883

Many contributions received this year were larger than usual, and some came from foreign countries, such as: Algiers, Morocco, Jugo-Slavia, Dutch

East Indies, Northern Rhodesia, Belgian Congo, Peru, Venezuela, and Canada.

5. Insignia Business:

Total number of key and pin orders received:

	1929		1930
Membership emblems	996		975
Associate emblems	315		450
Total	1311	vs.	1425

6. Fellowships:

A. Applications received	17
B. Applications granted	7
C. Amount granted (total)	\$3050.00

7. Miscellaneous Office Business:

Membership diplomas sent out	1550
Associate certificates sent out	2050
Index cards for chapter records and secretary's files	1710
Stationery	600 sheets stationery
	350 envelopes
Copies of the Constitution	318

Edward Ellery, *Secretary*

REPORT OF THE TREASURER FOR THE YEAR 1930

The treasurer takes pleasure in reporting that for the first time in a number of years the annual assessments of all chapters were paid well before the close of the year.

Receipts

Cash on hand, Jan. 1, 1930	$1137.29	
Chapter assessment for 1930	6125.00	
Chapter assessment, arrears for 1929	48.00	
Initiation fees for 1930	1740.00	
Initiation fees for 1929	367.00	
Sale of QUARTERLY	27.00	
Installation fees	250.00	
Sale of Insignia (1929 and 1930)	2061.75	
Surplus on dinner 1929	5.25	
Interest on investment	625.00	$12,386.29

Disbursements

Secretary's Office:		
Secretary's Assistants	$1618.50	
General	549.97	
Secretary's stipend	1800.00	
Addressograph	734.46	
Treasurer's Office:		
Clerical assistance	150.00	
Stamps	10.00	
Officers' travel expense	466.60	
QUARTERLY (4 issues)	1936.55	
Engrossing charters	210.35	
1 M Amer. Tel. & Tel. 5½% bond	1077.50	
1 M Canadian Pacific 5% bond	1010.00	
Accrued interest on above two bonds	10.18	
Cash on hand, Dec. 31, 1930	2812.18	$12,386.29

Investment Account—General
(Securities carried at cost)

$1000 Amer. Tel. & Tel. 5½% bond at	$1037.44
$1000 Amer. Tel. & Tel. 5% bond at	991.94
$1000 Consolidated Gas of New York 5½% bond at	1002.90
$1000 St. Louis & San Francisco Railway 4% bond at	796.35
$1000 Baltimore & Ohio Railroad 5% bond at	955.00
$1000 Pacific Gas & Electric Co. 5½% bond at	1045.00
$1000 Philadelphia Co. 5% bond at	979.50
$1000 Erie Railroad Co. 5% bond at	947.00
$1000 Southern Railway Co. 6% bond at	1152.00

$1000 Western Electric Co. 5% bond at	1029.50	
$1000 Philadelphia Co. 5% bond at	997.00	
$1000 New York Central 6% bond at	1032.00	
$1000 Canadian Pacific 5% bond at	1010.00	
$1000 Amer. Tel. & Tel. $5^1/_2$% bond at	1077.50	$14,053.13

Alumni Fund

Receipts

Cash on hand, Jan. 1, 1930	$ 534.94	
Receipts from subscriptions	3126.60	
Interest on investments	140.00	$3801.54

Disbursements

Research:			
Profs. W. P. Davey & W. R. Ham, 1929–30	$700.00		
Professor A. A. Bless, 1929–30	125.00		
Professor A. A. Bless, 1930–31	250.00		
Miss L. J. Grieff, for Profs. LaMer and Gronwall, 1929–30	500.00		
Miss Joyce Hedrick, 1929–30	60.00		
Miss Joyce Hedrick, 1930–31	120.00		
Dr. Icie G. Macy, 1930–31	450.00		
Professor A. H. Smith, 1930–31	300.00		
Professor N. E. A. Hinds, 1930–31	275.00		
Professor Jean Broadhurst, 1930–31	700.00	$3480.00	
Non-negotiable checks		8.00	
Collection charges		.95	
Cash on hand, Dec. 31, 1930		312.59	$3801.54

Alumni Fund Investment Account

(Securities carried at cost)

$1000 Dominion of Canada 5% bond at	$ 999.50	
$1000 Southern Pacific Co. $4^1/_2$% bond at	905.75	
$1000 Southern Pacific Co. $4^1/_2$% bond at	907.00	$2812.25

December 31, 1930 GEORGE B. PEGRAM, *Treasurer*

We have audited the accounts of the Treasurer of the Society of Sigma Xi for the year ending December 31, 1930, and certify that the income shown by the books of the Treasurer has been duly accounted for, that payments have been properly vouched and that the balance sheet and accounts submitted contain a true statement of the financial condition of the Society. We have also examined the securities in the hands of the Treasurer and find the following bonds: $3000 American Telephone and Telegraph Co.; $1000 Consolidated Gas of New York;

$1000 St. Louis and San Francisco Railway; $1000 Baltimore and Ohio Railroad; $1000 Pacific Gas and Electric Co.; $2000 Philadelphia Co.; $1000 Erie Railroad Co.; $1000 Southern Railway Co.; $1000 Western Electric Co.; $1000 New York Central; $1000 Dominion of Canada; $2000 Southern Pacific Co.; $1000 Canadian Pacific.

John T. Finneran
L. Brett
Auditors

January 21, 1931

THE INSTALLATION AT THE UNIVERSITY OF PITTSBURGH

The University of Pittsburgh Chapter of the Sigma Xi was formally installed on the afternoon of February eleventh at 3:30. The ceremonies of the installation had been planned to coincide with the mid-year commencement exercises of the University. The program of the day began at 11:30 A.M. with the granting of degrees to the graduating class. At the same time, and in honor of the occasion, the degree of Doctor of Science was conferred on the national representatives of Sigma Xi, Doctor G. W. Stewart and Dean Edward Ellery, and upon Doctor Harlow Shapley and Doctor G. E. Coghill. A luncheon given at the University Club by Chancellor Bowman followed the commencement exercises.

The installation proper took place at 3:30 in the afternoon. The petition for the Chapter was read by Professor Hance and Dean Ellery announced that it had been granted by the national convention in Cleveland, December 30, 1930. President Stewart presented the Charter to the new organization and in a simple, eloquent address charged the members with their responsibilities. Dean Ellery spoke of the possibilities of Sigma Xi for stimulating creative work and of some of the work of other chapters.

Nominations were received for Chapter officers and those elected were:

President.................... Davenport Hooker (Anatomy)
Vice-President...................... O. E. Jennings (Botany)
Treasurer........................ O. H. Blackwood (Physics)
Secretary....................... Robert T. Hance (Zoölogy)

A Board of Electors of eleven members representing the various scientific departments of the University of Pittsburgh was elected, as were also two additional members to act with the officers as the Executive Committee. The meeting then adjourned to reconvene at 4:30 P.M.

The Board of Electors presented nineteen names to the Chapter for approval. They were unanimously elected. The list of the new members is as follows:

George Hubbard Clapp, President of the Board of Trustees of the University of Pittsburgh and of the Carnegie Museum. Specialist in conchology and chemistry.

William Jacob Holland, Director-emeritus of the Carnegie Museum

and Chancellor-emeritus of the University of Pittsburgh. Entomologist and paleontologist.

Andrey Avinoff, Director of the Carnegie Museum. Entomology.

John Calvert Donaldson, Anatomy.

William Allen Hamor, Assistant Director of the Mellon Institute. Petroleum engineering and chemistry.

Roswell Hill Johnson, Oil and gas engineering.

Frank Craig Jordan, Director of the Allegheny Observatory.

George Rufus Lacy, Pathology, Bacteriology, Immunology.

Alexander Lowy, Organic Chemistry.

Maud Leonora Menten, Pathology.

William Swindler McEllroy, Physiological Chemistry.

Norman Leslie Munn, Psychology.

Abraham Louis Robinson, Chemistry.

William Thomas Root, Jr., Psychology.

Harold James Rose, Chemistry (Mellon Institute) Director of Research in Coal and Coke.

Arthur Edward Ruark, Physics.

Alexander Silverman, Chemistry.

Samuel Howard Williams, Zoölogy.

* * * * * *

The initiation of new members was followed by a banquet at the Hotel Schenley at six o'clock at which eighty-five were present.

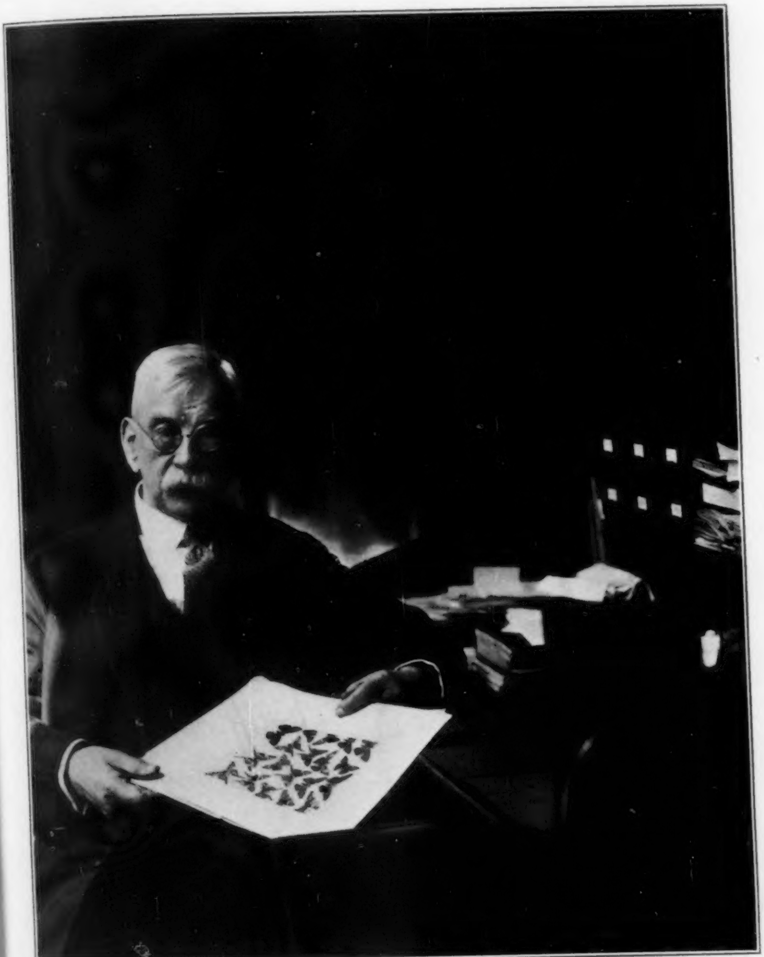
At 8:30 Doctor Harlow Shapley, Director of the Harvard Observatory, presented the first public lecture of the new chapter, entitled "New Explorations of the Stellar World."

The Chapters of Sigma Xi at the University of Pennsylvania, Swarthmore College, Pennsylvania State College, Case Scientific School and the Sigma Xi Club of the University of West Virginia sent representatives.

ROBERT T. HANCE, *Secretary*

WILLIAM JACOB HOLLAND

Although in his eighty-third year, Dr. Holland is possibly the youngest member of Sigma Xi. Born in 1848, he was initiated into the Pittsburgh Chapter in February, 1931. He has lead a busy life and has had a broad experience. Graduated from the Moravian College and Theological Seminary in Bethlehem, Pennsylvania in '67, he holds undergraduate and honorary degrees from a number of educational institutions, among them Amherst, Princeton, Washington and Jefferson, Dickinson, New York University, and St. Andrews. To his undergraduate studies he added preparation for the practice of medicine. He was a successful pastor for a number of years, and served the University of Pittsburgh as its Chancellor from 1891 to 1901. He has been a professor of Latin, a professor of political economy and international law, a lecturer in zoölogy, a director of the Carnegie Museum. An entomologist and paleontologist of note, he is not only clearly eligible to membership in Sigma Xi, but in accepting the membership he honors Sigma Xi.



Professor William Jacob Holland

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Clark, Har

Clark, Rob

Clark, Sidn

Clarke, Ch

Clawson, B

Claycomb,

Clevenger,
Cline, Albe
Cline, Justu

Clugh, Clai
Clyde, Har

Cobb, Fried
Cobe, Herb
Coburn, Ed

Cochran, D

Cochran, G
Cody, Bern

Coghlan, C

Cohen, Art

Cohen, Ma

Cole, Dale

Cole, Oris
Coleman, R
Coley, Clar
Collins, Ev

Collins, Fra

LIST OF MISSING PERSONS

Can You Help Us Locate These Members?

Name	*Chapter*	*Last Known Address*
Clark, Harold W.	Calif. 1923	2213 Union St., Berkeley, Calif.
Clark, Robert Watson	Michigan 1908	City Library, Okmulgee, Okla.
Clark, Sidney M.	Columbia 1911	c/o Griggs & Meyers, 110 West 40th St., New York City
Clarke, Charles Patrick	Minn. 1908	1234 Oakland Ave., Milwaukee, Wis.
Clawson, Ben J. (Prof.)	Kansas 1913, 21	Dept. of Pathology, University of North Dakota, Grand Forks, N. D.
Claycomb, George B.	Ill. 1919	Dakota Wesleyan University, Mitchell, S. Dakota
Clevenger, Joseph Franklin	Chicago, 1909	
Cline, Albert Collins	Syracuse 1922	
Cline, Justus Henry	Northwestern 1908	Matador Petrol Company, Box 930, Cheyenne, Wyoming
Clugh, Clair Isaac	Purdue 1926	Altoona, Pa.
Clyde, Harry Schley	Calif. 1924	Box "X," Pittsburgh, Calif.
Cobb, Frieda	Mich. 1919	
Cobe, Herbert M.	Stanford 1925	Ann Arbor, Mich.
Coburn, Edward B.	Columbia 1903	16 East 43rd St., New York City
Cochran, Donald Robb	Penn. 1921	24 Mount Vernon St., Boston, Mass.
Cochran, Grace	Iowa 1928	
Cody, Bernard Anthony (Dr.)	Stanford 1922	1745 E. Ocean, Long Beach, Calif.
Coghlan, Charles	Oregon 1924	U. of Oreg. Med. School, Portland, Oreg.
Cohen, Arthur	Chicago 1920	1250 Lincoln St., Chicago, Ill.
Cohen, Maurice Louis	Chicago 1922	1321 W. 12th St., Chicago, Ill.
Cole, Dale Stevens	Cornell 1912	Martell Packing Co., Elyria, Ohio
Cole, Oris Ivan	Purdue 1928	Indianapolis, Ind.
Coleman, Renick B.	Chicago 1922	Paris, Ky.
Coley, Clarence Tallman	Union 1903	
Collins, Everett Naughtin	Chicago 1919	Presbyterian Hospital, Chicago, Ill.
Collins, Frank H.	Idaho 1924	Chem. Dept., Kansas State Agri. Col., Manhattan, Kan.

Collins, Harold G.	Ohio 1922	
Collins, Melvin J.	Colo. 1918	
Collins, Ray Arthur	Ill. 1909	922 Crosby St., Akron, Ohio
Collison, Stanley Edgar	Ohio 1908	R. F. D. 4, Gorham, N. Y.
Colvard, Sidney Walter	Purdue 1917	843 N. Main St., Dayton, Ohio
Colvert, William W.	Chicago 1928	5926 Indiana Ave., Chicago, Ill.
Compere, Edward Lyon, Jr.	Chicago 1926	Rush Medical College, Chicago, Ill.
Conard, Harvey Evon	Ohio 1916	2554 Summit St., Columbus, Ohio
Conlee, George Dyer	Cornell 1908	Bailey Motor Co., 2015 East 46th St., Cleveland, Ohio
Connell, John T.	Stanford 1917	Stanford Univ., Calif.
Connor, Isaac Baum	Penn. 1908	6845 Gorston Ave., Roxborough, Pa.
Constant, Frank Woodbridge	Yale 1928	17 Compton St., New Haven, Conn. (or) 57 Battle Rd., Princeton, N. J.
Cook, William George	Mich. 1904	5206 Winthrop Ave., Chicago, Ill.
Coon, John Sayler	Cornell 1888	26 Kimball St., Atlanta, Ga.
Cooper, Albert R.	Ill. 1916	7011 Perry Ave., Chicago, Ill.
Cooper, Clark N.	Iowa 1928	Univ. of Iowa Med. School, Iowa City, Iowa
Cooper, Grace Beers	Mich.	Kalamazoo, Mich.
Corning, Leo H.	Case 1918	1237 Melbourne Rd., Cleveland, Ohio
Cornwall, H. B. (Dr.)	Columbia 1905	
Corson, Harold Tuttle	Mich. 1918	Univ. of Mich, Ann Arbor, Mich.
Cort, J. E.	Ill. 1912	....
Costa, Joseph David	Calif. 1924	Oxford Apts., Berkeley, Calif.
Coulson, Raymond Chester	Ohio 1924	123 Olentangy St., Columbus, Ohio
Courtney, Robert Hall	Purdue 1923	c/o F. R. Muller & Co., Waukegan, Ill.
Covell, Mark Bertram, Jr.	Mich. 1921	Gen. Elec. Co., Schenectady, N. Y.

CHAPTER OFFICERS

List Furnished by the Secretaries of the Chapters

Chapter	President	Vice-Pres.	Secretary	Treasurer
Cornell........	H. H. Love....	A. A. Allen....	W. A. Hagan...	A. J. Heinicke
Rensselaer....	E. R. Cary.....	F. W. Schwartz	F. M. Sebast...	H. E. Stevens
Union.........	J. W. Mavor...	D. S. Morse....	C. B. Hurd....	C. B. Hurd
Kansas........	E. B. Stouffer..	H. H. Lane....	J.C.Stranathan	H. E. Jordan
Yale..........	J. S. Nicholas..	R. H. Suttie....	R. K. Warner..	A. T. Waterman
Minnesota....	H. A. Erikson..	D. E. Minnich..	D. G. Paterson..	C. O. Rost
Nebraska.....	G. L. Peltier...	E. R. Walker...	E. N. Anderson	M. G. Gaba
Ohio..........	E. N. Transeau.	W. J. Kostir...	F. A. Hitchcock	F. A. Hitchcock
Pennsylvania .	F. H. Safford...	C. W. Burr....	H. S. Oberly...	R. W. Duncan
Brown........	W. H. Snell....	A. A. Bennett..	W. A. Castle...	C. E. Bennett
Iowa..........	F. A. Nagler...	W. F. Loehwing	L. E. Travis....	J. A. Eldridge
Stanford......	S. D. Townley..	W. F. Dietrich..	M. L. Huggins..	M. L. Huggins
California.....	J. Grinnell.....	R. W. Chaney..	P. Byerly......	F. H. Cherry
Columbia.....	L. T. Work.....	S. M. Quimby .	W. A. Curry ...	W. A. Curry
Chicago......	E. O. Jordan...	E. S. Bastin....	T. F. Young...	Walter Bartley
Michigan.....	H. B. Lewis....	A. H. White....	B. A. Soule....	Margaret Johnston
Illinois.......	C. T. Knipp...	R. Graham.....	J. E. Lamar....	J. O. Draffin
Case.........	W. E. Wickenden.........	C. Nusbaum...	K. H. Donaldson..........	T. M. Focke
Indiana.......	D. A. Rothrock	J. M. Van Hook	E. L. Yeager...	E. L. Yeager
Missouri......	E. S. Haines...	L. J. Stadler...	A. E. Stearn....	M. J. Guthrie
Colorado.....	A. J. Kempner.	Edna Johnson.. (Denver) R. Whitehead..	G. Wakeham...	W. K. Nelson
Northwestern.	F. D. Barker...	J. P. Simonds...	H. B. Ward....	Lois W.Griffiths
Syracuse......	C. C. Forsaith..	C. C. Carpenter	D. P. Randall..	R. R. Hirt
Wisconsin.....	Warren Weaver	F. Daniels.....	A. J. Riker.....	H. R. Aldrich
Univ. of Wash.	H. Wilson......	E. V. Lynn.....	G. E.Goodspeed	V. Sivertz
Worcester.....	J. W. Howe....	H. H. Newell...	H. J. Gay.....	F. R. Butler
Purdue.......	R. G. Dukes...	M. W. Gardner.	R. E. Nelson...	R. B. Abbott
Washington University..	T. R. Ball.....	C. F. Hagenow.	E. S. Reynolds..	H. G. Hake
District of Columbia...	C. R. Ball.....	R. H. Bogue...	G. L. Keenan..	M. G. Zehner
Texas........	C. P. Boner....	F. M. Bullard..	M. Y. Colby...	H. R. Henze
Mayo Foundation.....	W. Boothby....	E. S. Judd.....	A. E. Osterberg	A. E. Osterberg
N. Carolina...	O. Stuhlman...	J. N. Couch....	E. T. Browne. .	E. T. Browne
N. Dakota....	G. C. Wheeler..	R. C. Staley...	E. A. Baird....	E. A. Baird
Iowa State College (formerly *Ames*)	D. W. Snedecor	E. I. Fulmer....	C. H. Werkman	C. S. Gwynne
Rutgers......	T. J. Murray...	Wm. Rieman, 3rd..........	R. L. Starkey ..	M. A. Chrysler
McGill.......	H. M. Mackay.	W. G. McBride. F. E. Lloyd....	G. W. Scarth...	J. Beattie
Kentucky.....	W.W. Dimock..	C. C. Jett......	M. N. States...	G. C. Bassett
Idaho........	A. W. Fahrenwald........	C. Wakeland...	L. C. Cady.....	Ella Woods
Swarthmore...	S. C. Palmer...	E. H. Cox.....	H. J. Creighton	H. J. Creighton
Oregon.......	A. R. Sweetser.	W. F. Allen....	R. H. Seashore.	L. Friedman
Virginia	A. F. Benton...	L. T. Royster..	J. R. Roberts..	J. K. Roberts

CHAPTER OFFICERS (*Continued*)

LIST FURNISHED BY THE SECRETARIES OF THE CHAPTER

CHAPTER	PRESIDENT	VICE-PRES.	SECRETARY	TREASURER
Johns Hopkins	J. T. Singewald	A. W. Schultz...	M. W. Pullen..	F. D. Murnaghan
Calif. Institute of Technology	R. W. Sorensen	P. W. Merrill...	W. V. Houston..	L. C. Pauling
New York University .	H. W. Stunkard	B. G. Smith....	R. T. Cox......	R. T. Cox
Univ. of Cincinnati.....	G. D. McLaughlin..........	W. H. Bucher..	S. B. Arenson ..	S. B. Arenson
Mich. State College.....	W. Giltner.....	J. W. Crist.....	E. D. Devereux	E. F. Woodcock
Arizona.......	A. E. Douglass.	A. A. Stoyanow	T. F. Buehrer..	T. F. Buehrer
Lehigh.......	C. C. Bidwell..	J. B. Reynolds.	G. E. Doan....	C. D. Jensen
Maryland.....	E. C. Auchter..	W. B. Kemp...	M. M. Haring..	M. M. Haring
Kansas State College.....	D. L. Bushnell	C. O. Swanson..	C. W. Colver...	M. C. Sewall
Col. of Medicine, Univ. of Illinois...	W. F. Petersen.	W. J. R. Camp.	W. H. Welker..	I. Pilot
Pennsylvania State College	R. L. Sackett...	D. C. Duncan..	D.F.McFarland	J. E. DeCamp
Oklahoma....	W. M. Schriever	A. J. Neill.....	L.E.Swearingen	L.E.Swearingen
State College of Wash....	C. I. Erickson.	W. E. Bradt...	R. W. Gelbach..	R. W. Gelbach
Wyoming.....	Cecil Elder.....	J. A. Hill......	Carl S. Gilbert	Carl S. Gilbert
Rochester.....	V. J. Chambers.	G. W. Corner..	Q. D. Singewald	Q. D. Singewald
Pittsburgh....	D. Hooker....	O. E. Jennings.	R. T. Hance...	O.H. Blackwood

EASURER

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l S. Gilbert
D. Singewald
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CLUB

Southern
Californ
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Carleton
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University
Denver.
Oregon St
Agricult
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Maine..
University
Pittsbur
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Alabama
University
Arkansas
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Davis...
University
Utah....
Clark
Universit
St. Louis
Universit
Connecticu
Agr. Col
Miami Un
Univ. of Ga
Bucknell
Universit
Duke Univ
Buffalo....
Oklahoma
and M. C
lege.....
University
Denver..
Univ. of
Calif. at
Los Ange
Montana
State Coll

Club	President	Vice-Pres.	Secretary	Treasurer
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All changes of address and all other correspondence should be addressed to the secretary of Sigma Xi, Edward Ellery, Union College, Schenectady, N. Y.